

EUV exposure systems for volume production

SEMATECH Symposium Taiwan
Sep 7 2010

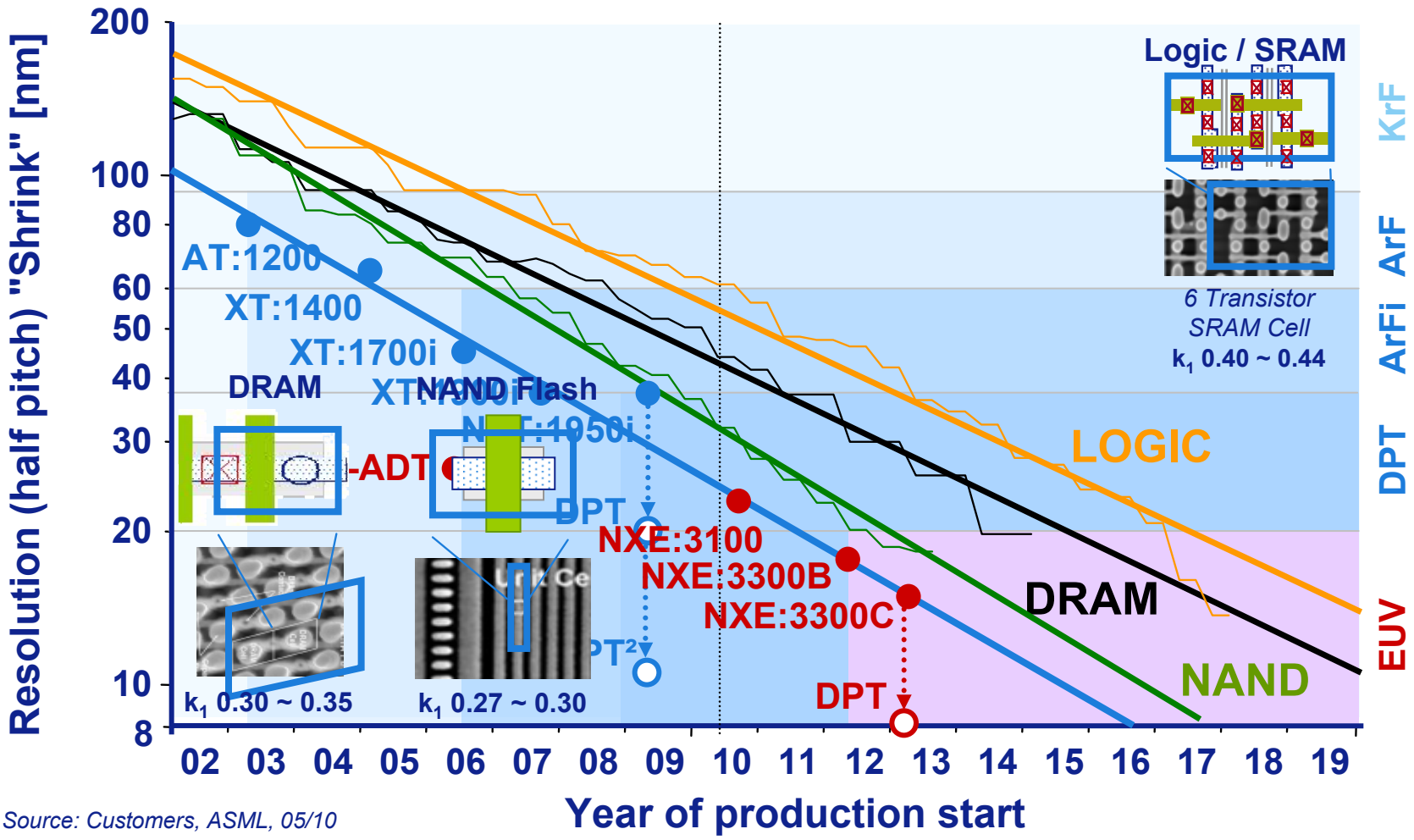
Alek Chen

Director, Technology Development Center - Asia

Outline

- ASML Product Roadmap to support Moore's law
- Progress on the 0.25NA system (NXE:3100)
- Progress on the 0.32NA system (NXE:3300)
- Summary

IC & Lithography roadmap towards <10nm

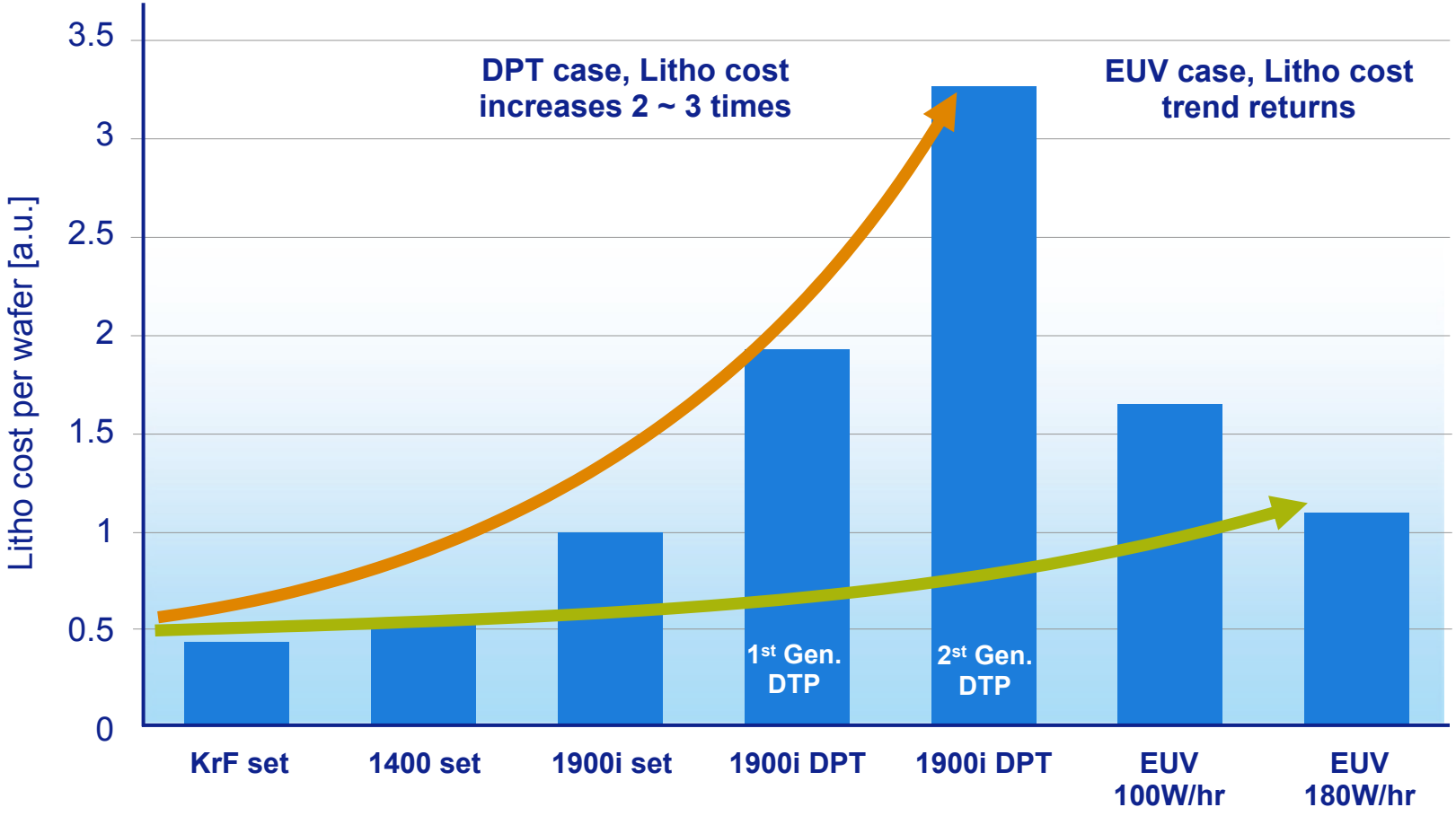


Source: Customers, ASML, 05/10

Notes:
1. R&D solution required 1.5~ 2 yrs ahead of Production
2. EUV resolution requires 7nm diffusion length resist
3. DPT = Double Patterning

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Litho costs back to normal with EUV >100 W/hr

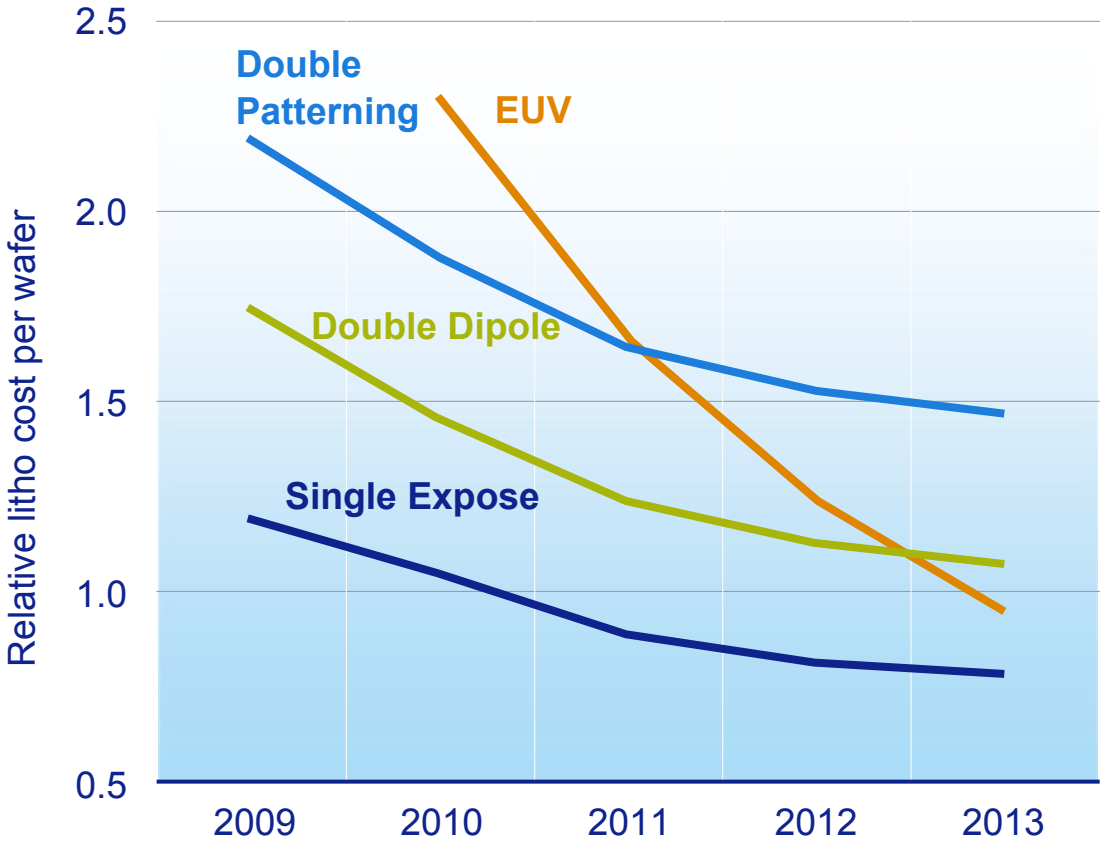


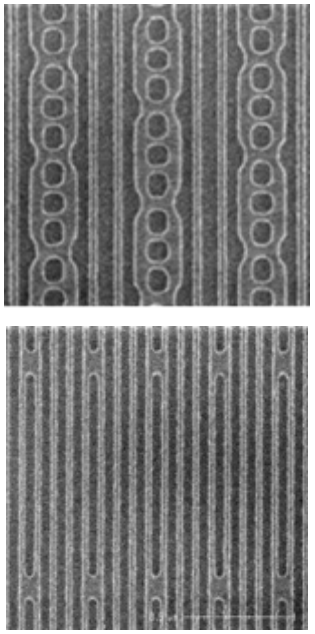
Source: Samsung, Prague, oct 2009

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EUV is the only feasible litho technology for foundries

Enabling cost effective shrink to 2x nm without design restriction





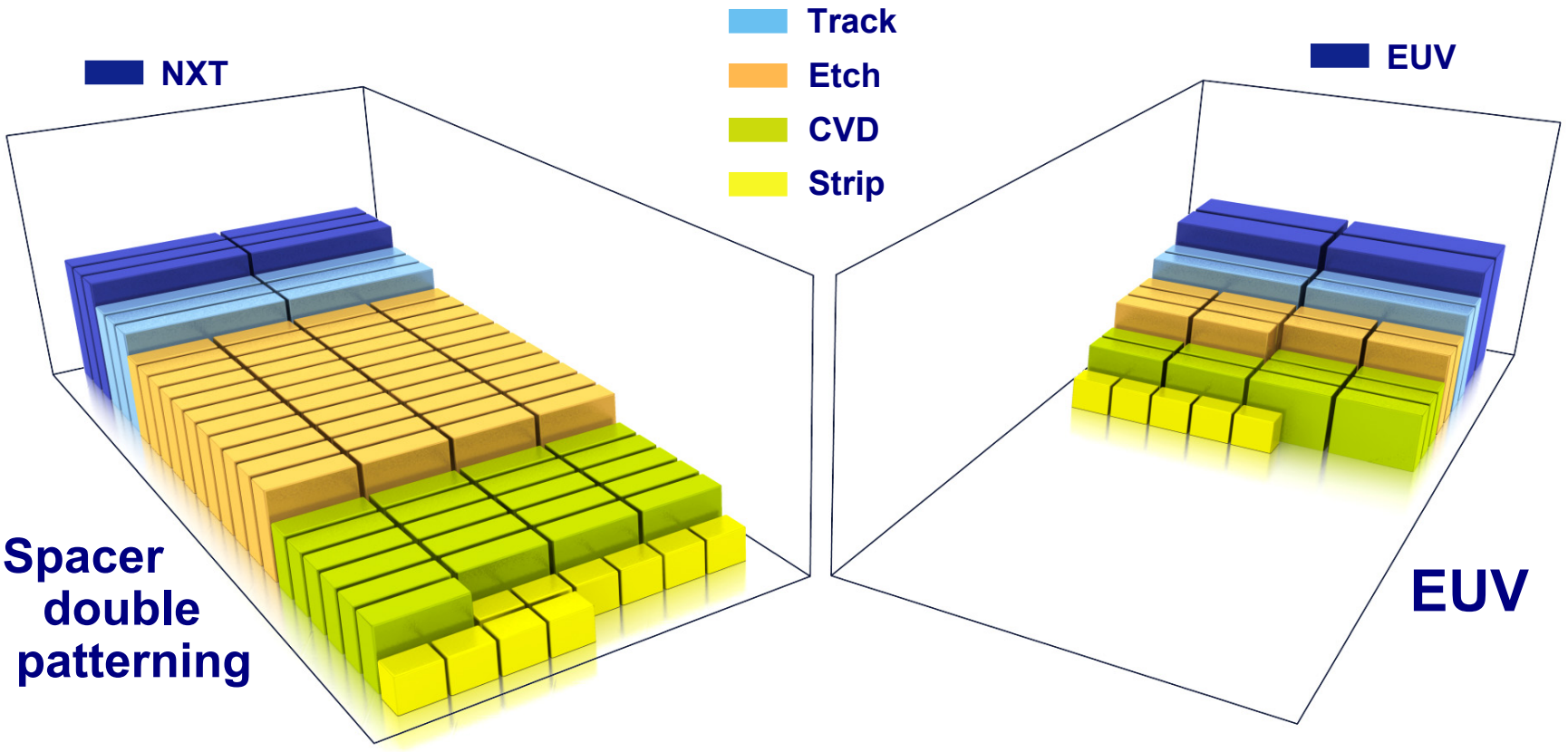
2X nm node metal and contact 0.25NA Proto tool courtesy tsmc Feb/2010

Source: TSMC, Prague 2009, and Feb 2010

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EUV can increase productivity for critical layers

Larger footprint required to support Multi Patterning schemes



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Critical issues EUV 2005-2009

2005 / 32hp	2006 / 32hp	2007 / 22hp	2008 / 22hp	2009 / 22hp
1. Resist resolution, sensitivity & LER met simultaneously	1. Reliable high power source & collector module	1. Reliable high power source & collector module	1. Long-term source operation with 100 W at IF and 5MJ/day	1. MASK
2. Collector lifetime	2. Resist resolution, sensitivity & LER met simultaneously	2. Resist resolution, sensitivity & LER met simultaneously	2. Defect free masks through lifecycle & inspection/review infrastructure	2. SOURCE
3. Availability of defect free mask	3. Availability of defect free mask	3. Availability of defect free mask	3. Resist resolution, sensitivity & LER met simultaneously	3. RESIST
4. Source power	4. Reticle protection during storage, handling and use	4. Reticle protection during storage, handling and use	• Reticle protection during storage, handling and use	• EUVL manufacturing integration
▪ Reticle protection during storage, handling and use	5. Projection and illuminator optics quality & lifetime	5. Projection and illuminator optics quality & lifetime	• Projection / illuminator optics and mask lifetime	
▪ Projection and illuminator optics quality & lifetime				

Source: Int'l SEMATECH, EUVL Symposium, Prague (Czech Republic), 2009

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ASML EUV Product Roadmap on target

Source roadmap in place for immersion compatible productivity

	2006 Proto System	2010 NXE:3100	2012 NXE:3300B	2013 NXE:3300C
Resolution	32 nm	27 nm	22 nm	16* nm
NA / σ	0.25 / 0.5	0.25 / 0.8	0.32 / 0.2-0.9	0.32 / OAI
Overlay (SMO)	< 7 nm	< 4.5 nm	< 3.5 nm	< 3 nm
Throughput W/hr	4 W/hr	60 W/hr	125 W/hr	150 W/hr
Dose, Source	5 mJ/cm^2, ~8 W	10 mJ/cm^2, >100 W	15 mJ/cm^2, >250 W	15 mJ/cm^2, >350 W

Main improvements
1) New EUV platform: NXE
2) Improved low flare optics
3) New high sigma illuminator
4) New high power source
5) Dual stages

Main improvements
1) New high NA 6 mirror lens
2) New high efficiency illuminator
3) Off-axis illumination optional
4) Source power increase
5) Reduced footprint

Platform enhancements
1) Off-Axis illumination
2) Source power increase

* Requires <7 nm resist diffusion length

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EUV process viability confirmed by two 0.25NA Systems



Source: IMEC (Leuven, Belgium)

λ	13.5 nm
NA	0.25
Field size	26 x 33 mm^2
Magnification	4x reduction
σ	0.5

- 300mm Single stage
- linked to track
- Single reticle load
- Uses TWINSCAN technology
- Sn discharge source

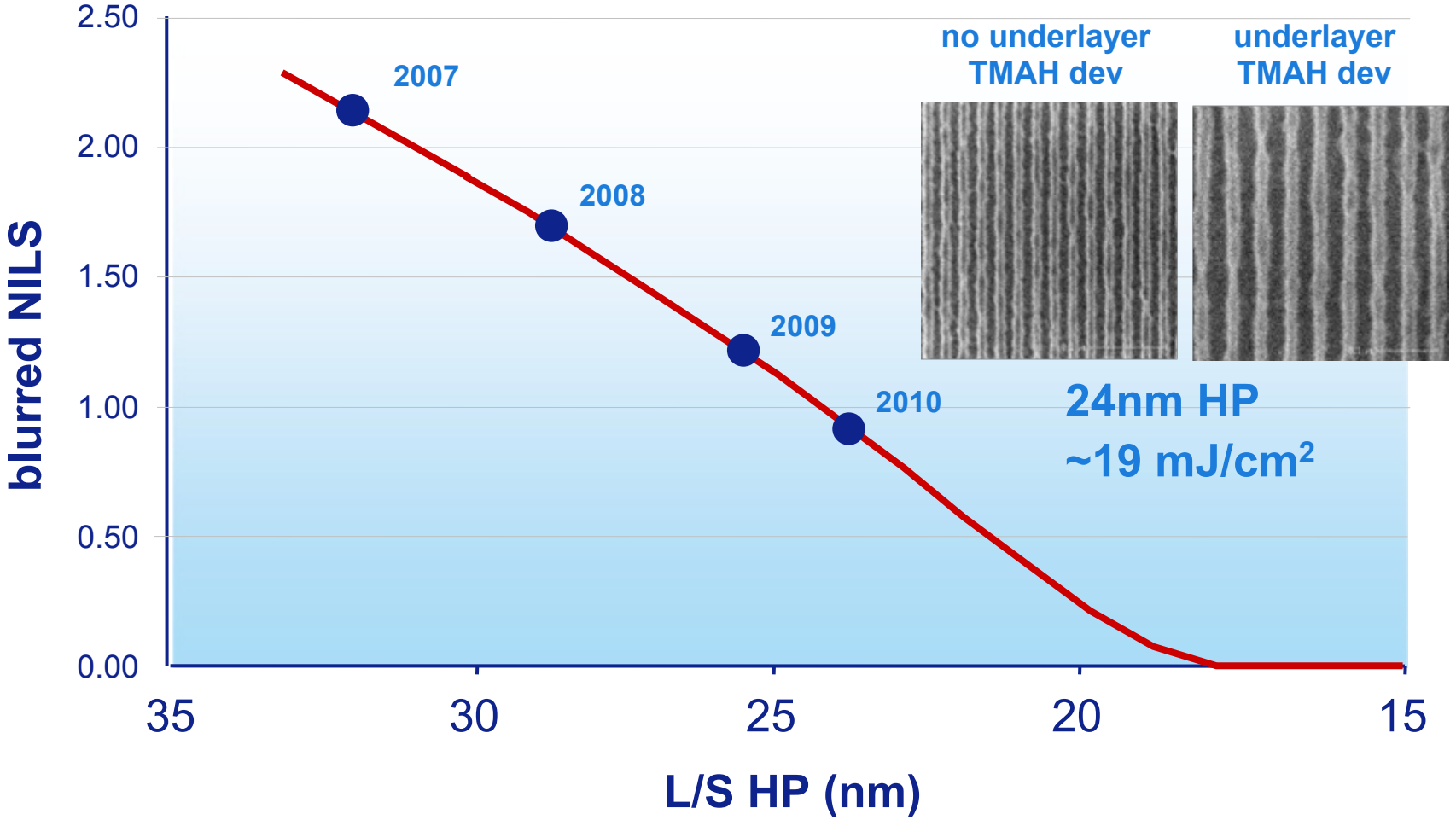


Source: University of Albany (Albany, NY) USA

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24nm champion resolution on 0.25NA/0.5σ system

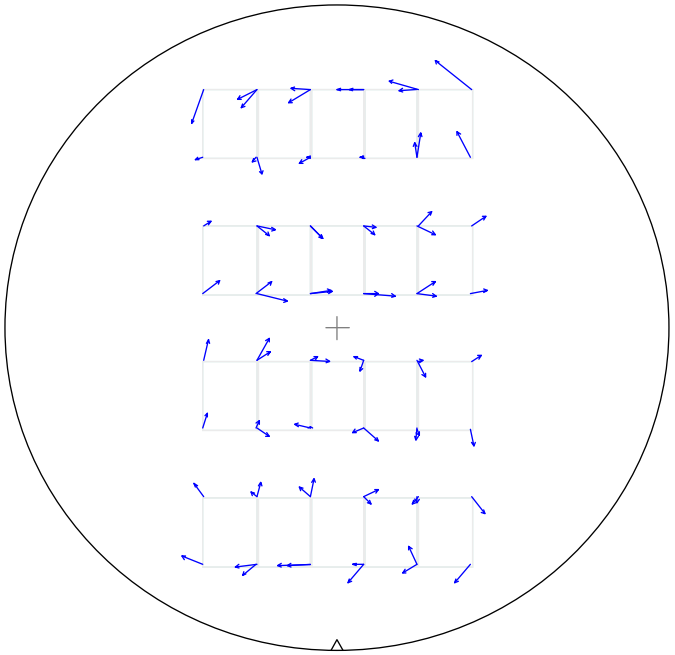
From ~32nm half-pitch in 2007 to 24nm in 2010



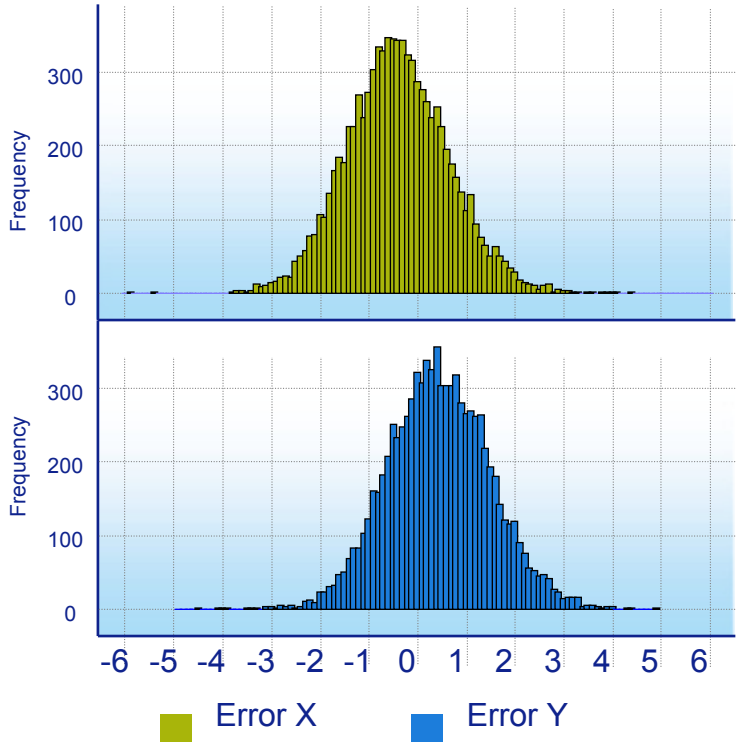
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Overlay performance supports device integration

On-product Overlay Residuals
X = 8.0 nm, Y = 7.8 nm



Single Machine Overlay
X = 2.2 nm, Y = 2.8 nm

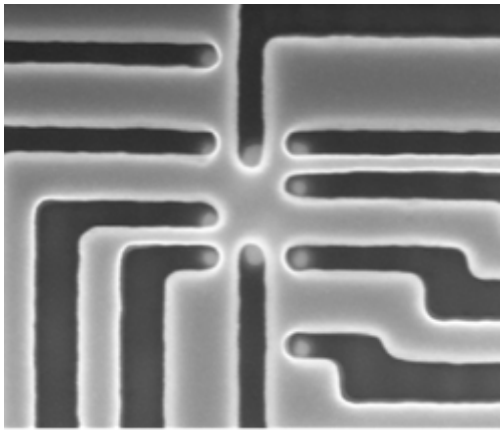


source: Global Foundries
Obert Wood et al, SPIE Adv Litho 2010

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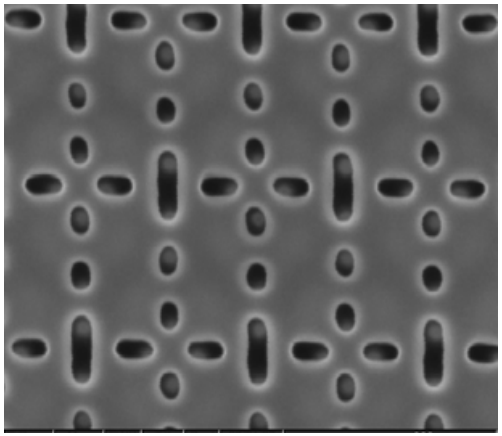
22 nm (0.079mm^2) node SRAM after etch process integration

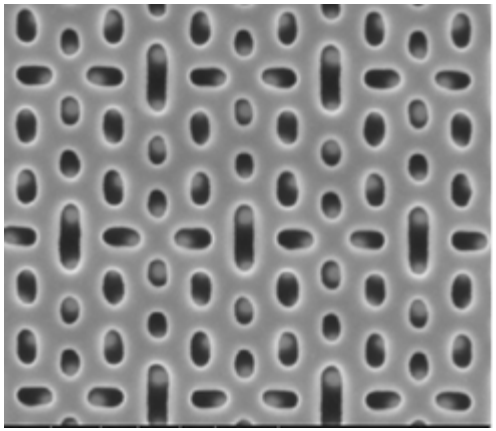
SRAM cell



Node [nm]	Half Pitch [nm]	Cell size [µm^2]	Cell size shrink
45	80	0.314	
45	70	0.274	13%
32	62	0.186	32%
22	**52**	**0.079**	**58%**
16	35	0.042	47%

SRAM array





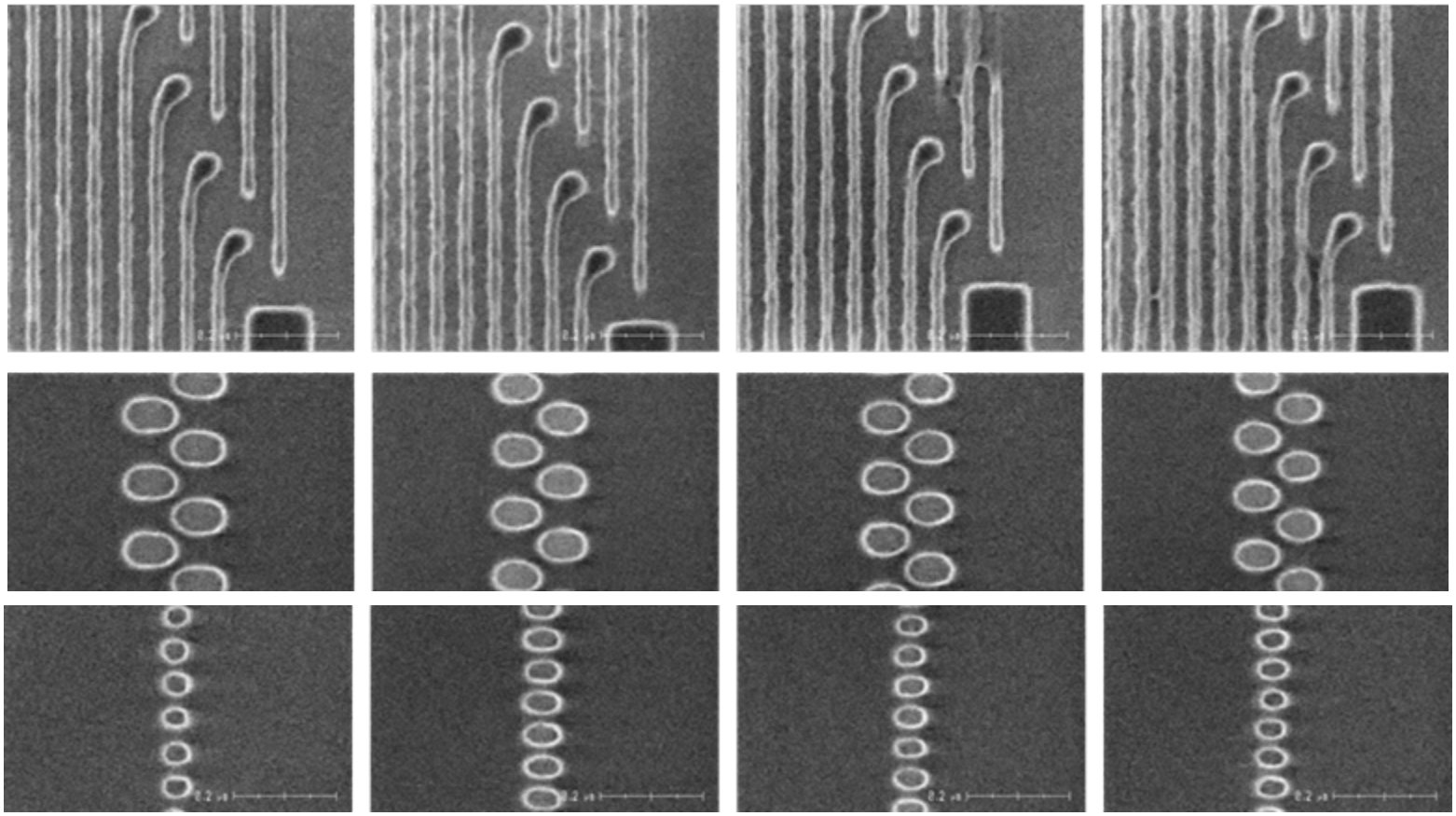
Ref.: M. Goethals et al., EUVS'09 in Prague

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NAND word line connectivity area down to 26 nm

staggered and slot contacts

30 nm L/S | 28 nm L/S | 27 nm L/S | 26 nm L/S

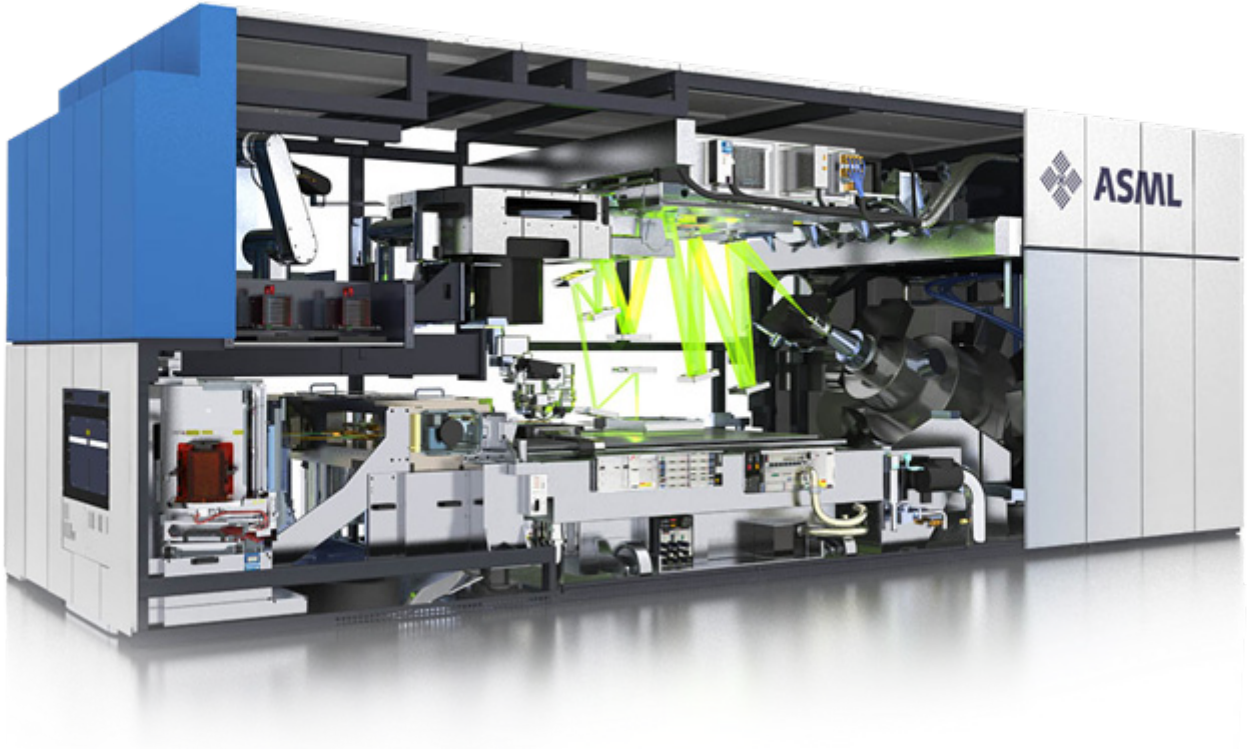


Mask funded by EU EXEPT program
in cooperation with IMEC

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NXE:3100 supports 27 nm at 60wph

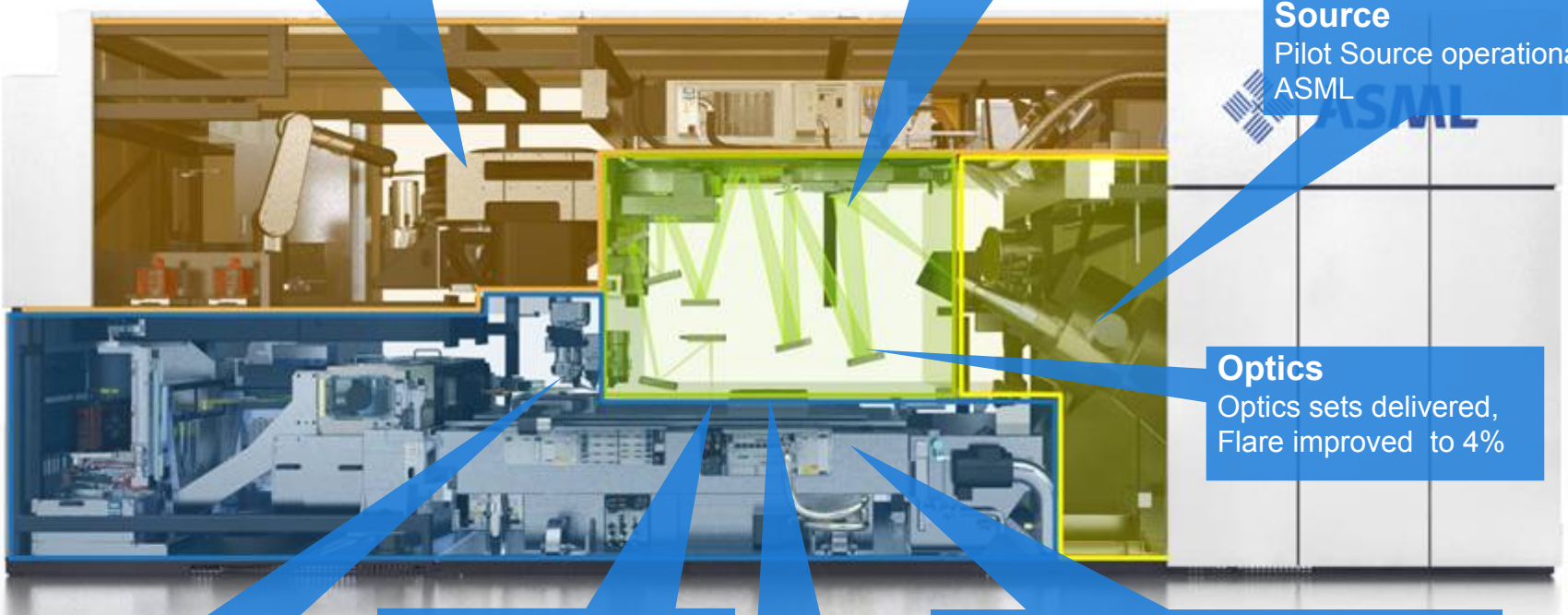
1st generation of NXE platform



- NA=0.25
- Sigma=0.8
- Resolution 27 nm
- SMO=4.5 nm
- MMO=7.0 nm
- Productivity 60wph at 10mJ/cm^2 resist

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NXE:3100 integration status



Reticle Stage and Handler
Reticle handling and stage control in vacuum
Reliability testing since Q4/2009

Vacuum
System design verified, <1hour pump down

Source
Pilot Source operational at ASML

Optics
Optics sets delivered,
Flare improved to 4%

Metrology
Alignment and Leveling demonstrated, Metrology position fully functional

Overlay
Ongoing

Imaging
First wafers exposed

Wafer Stage and handler
Wafer handling and scanning in vacuum
Reliability testing since Q4/2009

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NXE:3100 integration: 4 systems completed



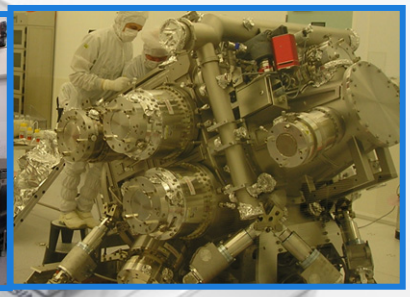
NXE:3100 #4



System completed

NXE:3100 #3









System completed
First wafer exposed
Integration for Imaging

NXE:3100 #2





NXE:3100 #1

System completed
Integration for Overlay, S/W, TPT

PUBLIC

2 more NXE:3100 systems in build-up

NXE:3100 #5

Currently used for Stage test setup



NXE:3100 #6



System in buildup



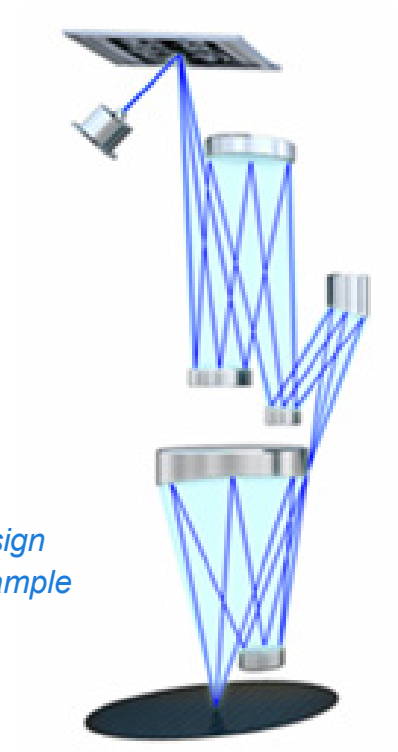


2 more Cabins used as work centers / test rigs. All 8 cabins can be used for NXE:3300 manufacturing

PUBLIC

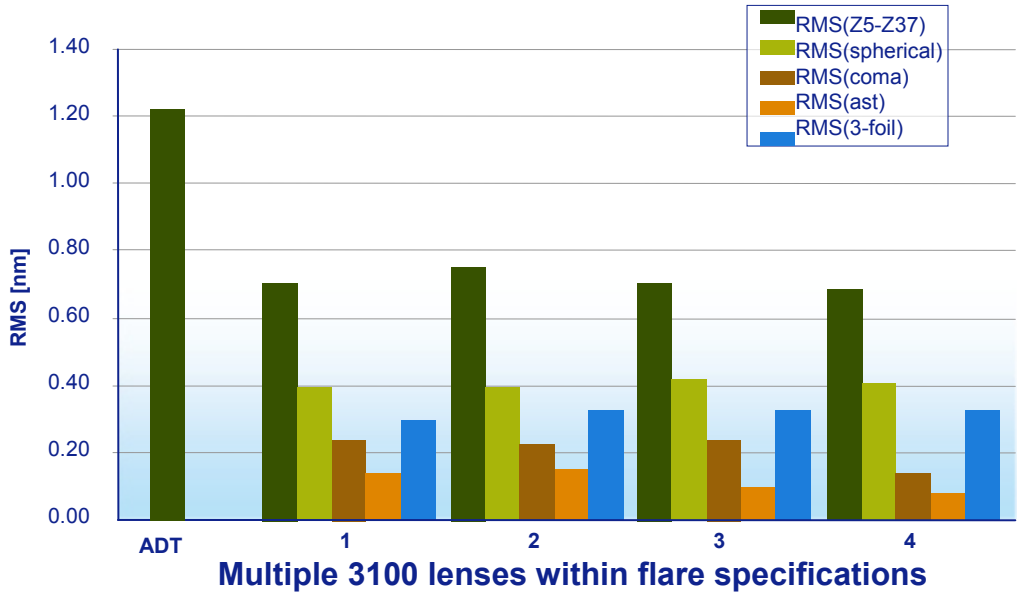
Multiple 3100 lenses manufactured and qualified

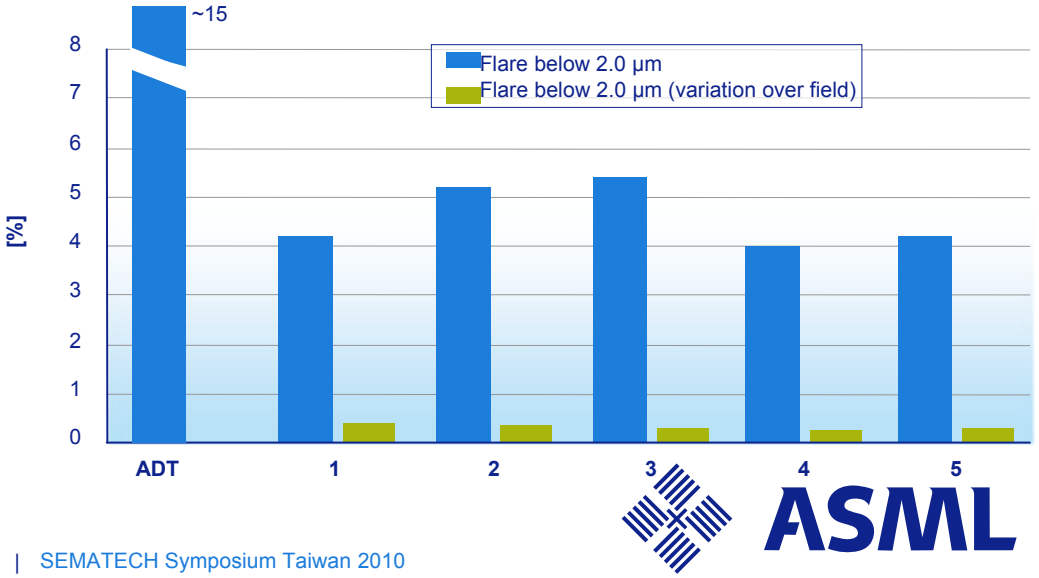
Wavefront qualified by EUVL interferometer



design example

- Field size: 26mm
- Chief ray at mask: 6°
- 4x reduction ring field design
- Design is extendable to higher NA

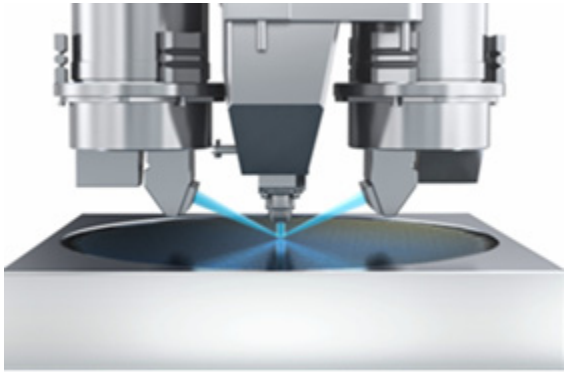


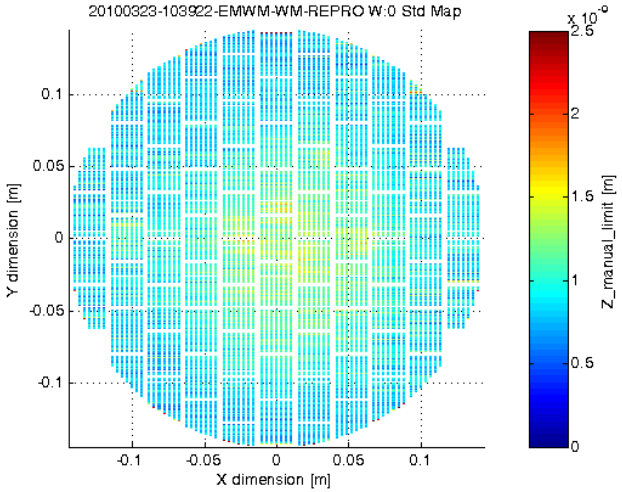


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NXE metrology verified in vacuum

Focus and Levelling

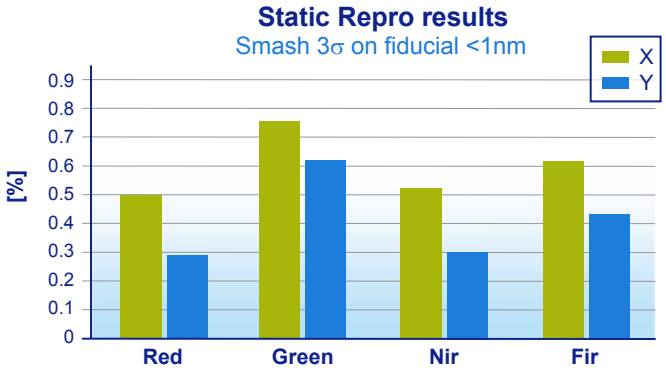


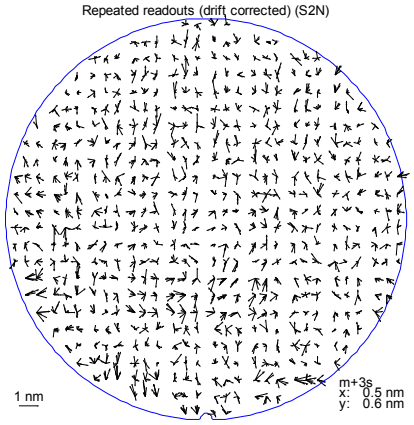


Mean standard deviation over wafer: 0.9 nm

99.7% value of standard deviations: 1.6 nm

Alignment





Multiple wafer readout
3σ = 0.6 nm

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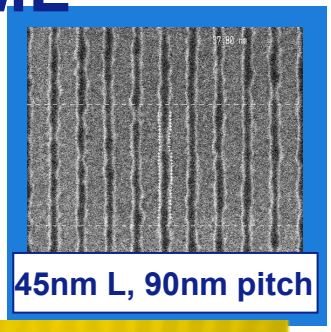
Sources integrated with systems at ASML

First EUV exposures made

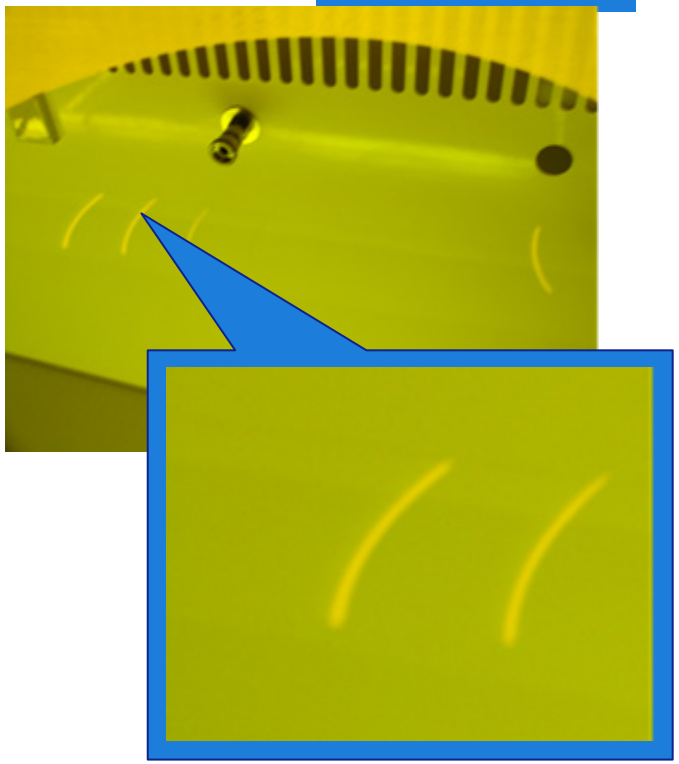


Source vessel operational and integrated with scanner system

First full field exposure under scanning mode



First EUV wafer exposed on integrated system





CO_2 laser operational and integrated with scanner system

ASML

On-site source performance: current and expectation

Performance as installed at ASML

- Two sources shipped to ASML, 3rd one in acceptance testing.
- Two power upgrades* are planned
 - Upgrade #1
 - Increased CO_2 power by increased laser gain length.
 - Upgrade #2
 - Increased CO_2-to-EUV conversion efficiency.

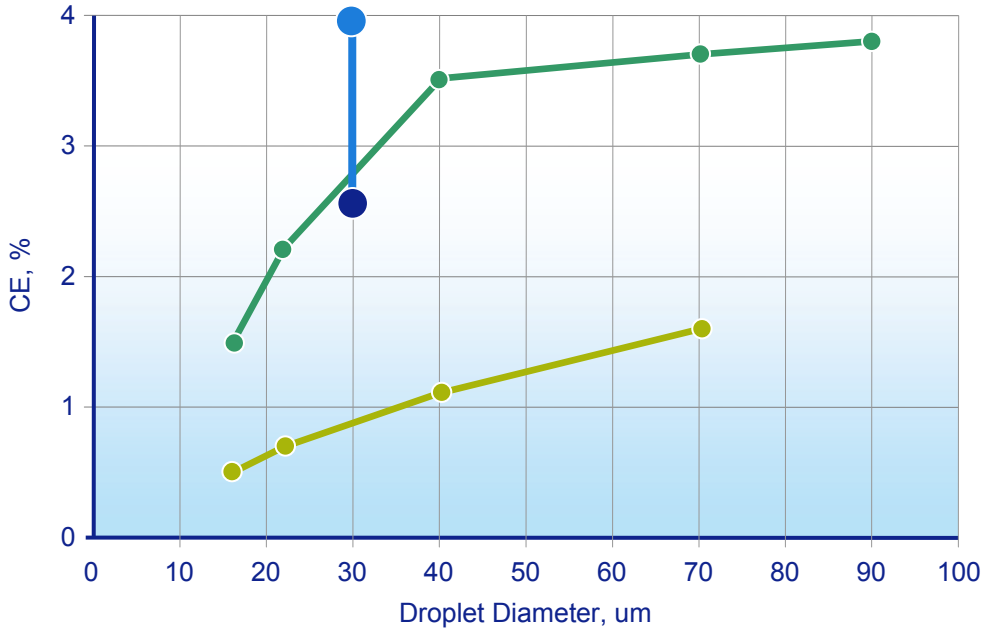
Source Configuration	Raw Power	Expose Power
Baseline	40 W	20 W
Upgrade #1	80 W	40 W
Upgrade #2	200 W	100 W

- Stable collector performance achieved on proto source.

*Ref.: D.C. Brandt (Cymer), SPIE 2010.

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Upgrade #2: Pre-pulse proof-of-concept being validated



With Pre-Pulse
Without Pre-Pulse

pulse-peak CE, measured 2Q'10
pulse-average CE, measured 2Q'10

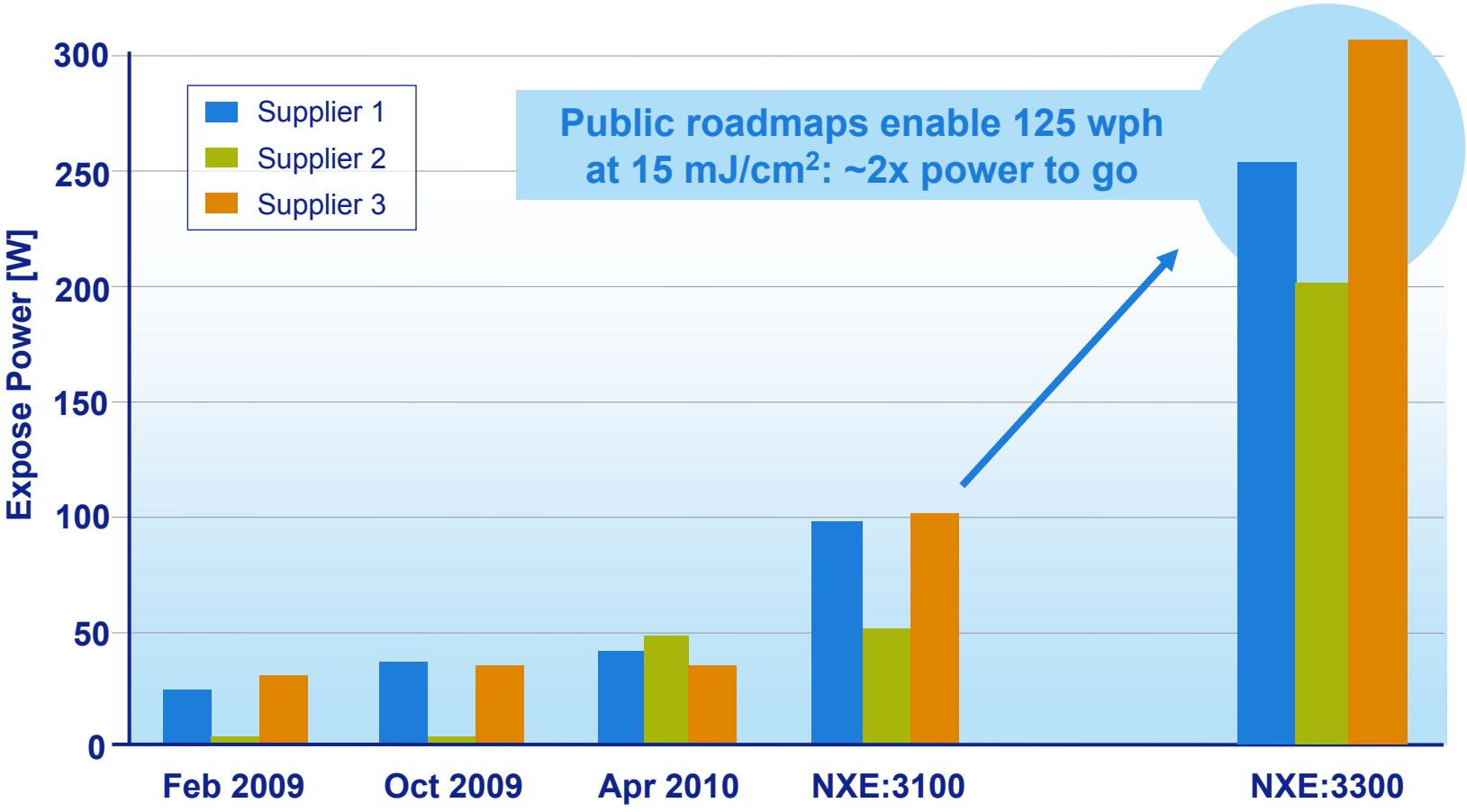
- The target size and density can be optimized by striking the droplet with a pre-pulse laser.
- The energy of the pre-pulse laser is much less than the main pulse and acts to expand the droplet size and reduce its density.
- Both the energy and timing of the pre-pulse can be adjusted to achieve best performance.

Ref.: D.C. Brandt (Cymer), SPIE 2010.

ASML

Significant source progress required for NXE 3300

Roadmap commitments from multiple suppliers enable NXE productivity



Source: Cymer, Ushio, Gigaphoton, SPIE 10, Gigaphoton Press release April 2010
published data scaled with dose control and spectral filtering losses
Data April 2010: Cymer – 30um droplets, Gigaphoton 60um droplets

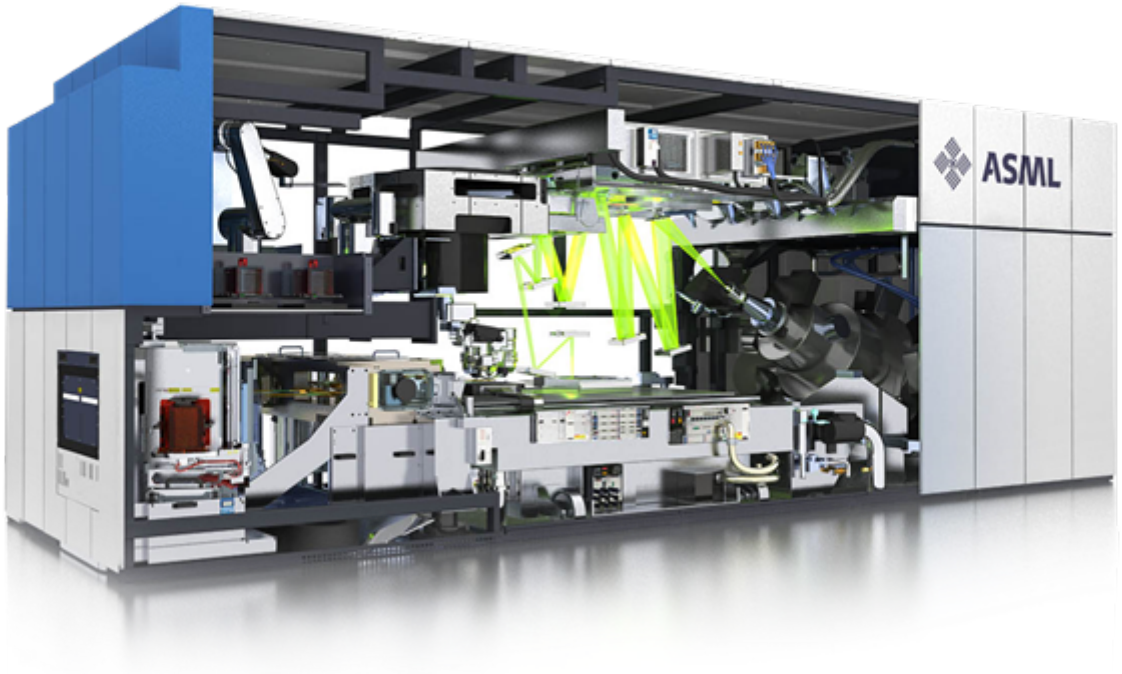
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NXE:3300B 1st shipment: H1 2012

2nd generation of NXE platform



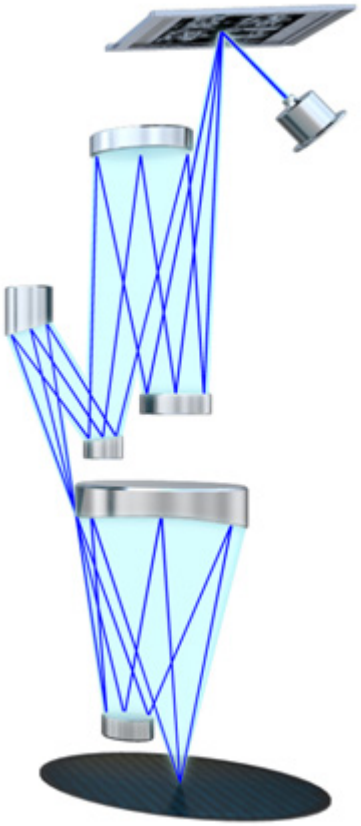
Specifications

- NA = 0.32
- Resolution 22 nm; 18/16nm with OAI
- Overlay 3.5 nm
- Productivity 125 wph 15 mJ/cm^2 resist

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Six-mirror lens design is extendable to 0.32 NA

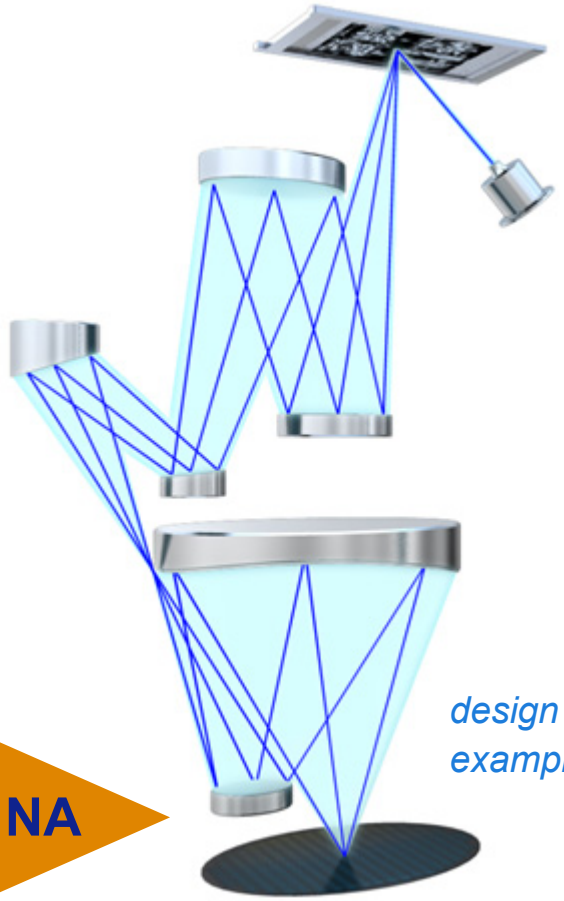
Resolution improves from 27 to 22 nm



- Field size 26 mm
- Chief ray at mask 6°

- Design complexity/cost increases
 - Larger mirrors
 - Steeper aspheric mirrors
 - High angles of incidence

0.25 NA → **0.32 NA**



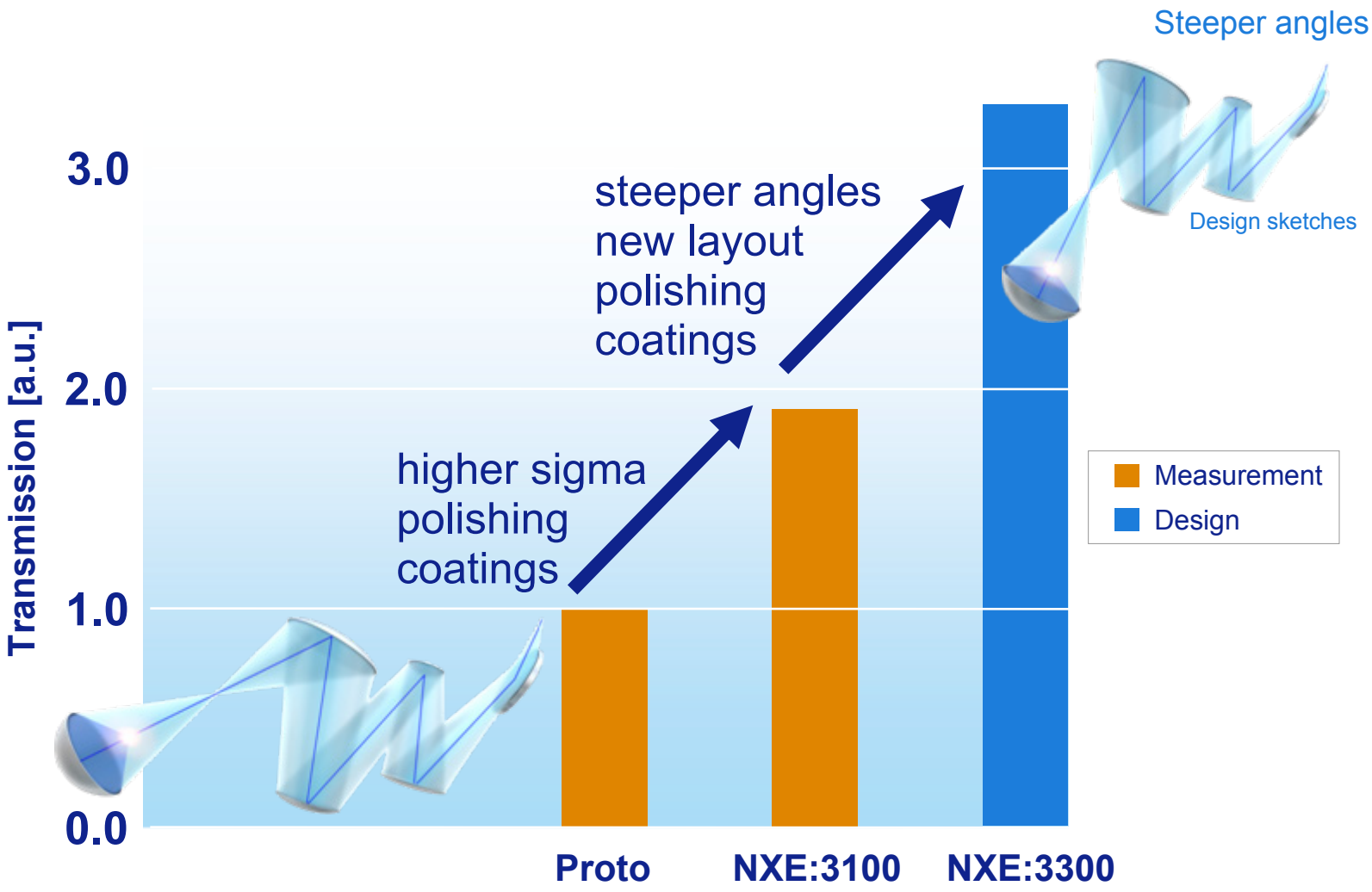
design examples

NXE:3100

NXE:3300

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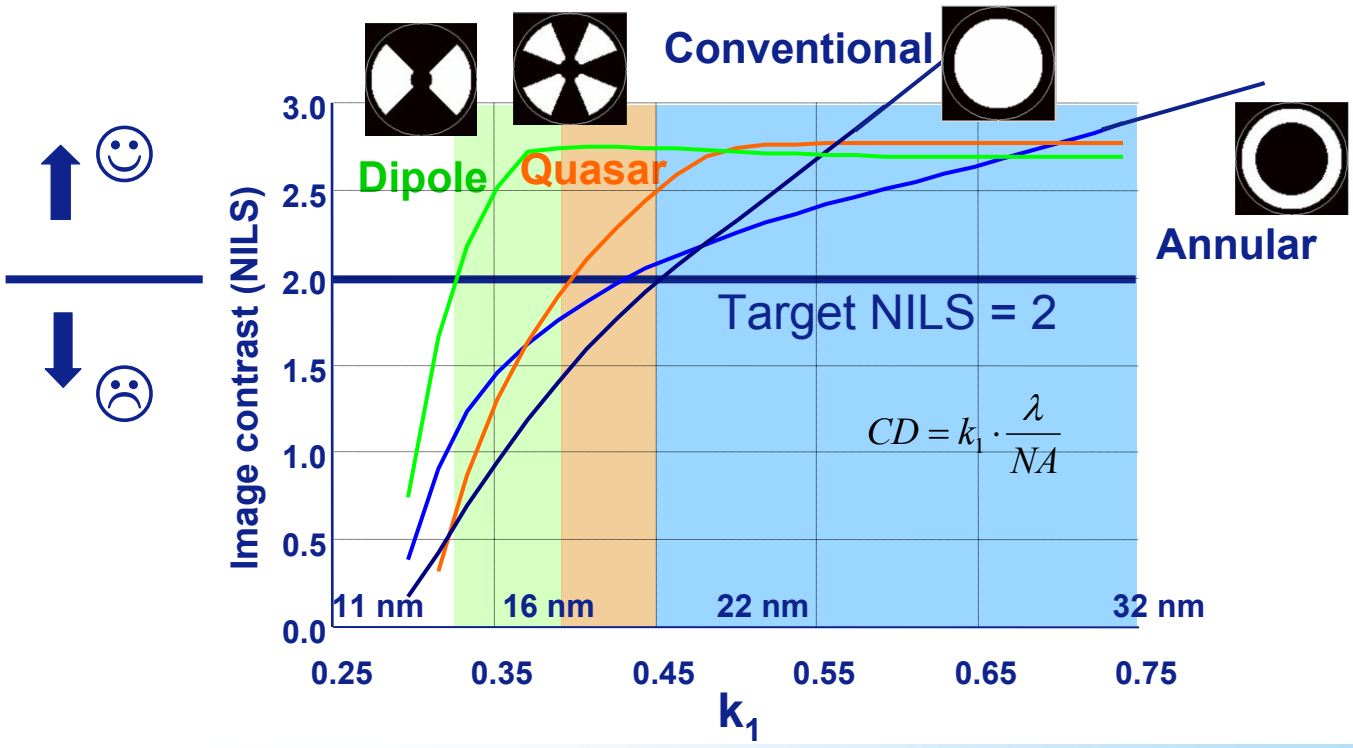
System Transmission significantly improved



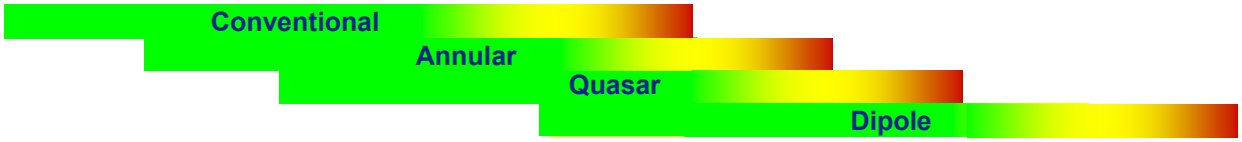
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Further resolution improvement with off-axis illumination

With dipole illumination resolution improves to below 16 nm



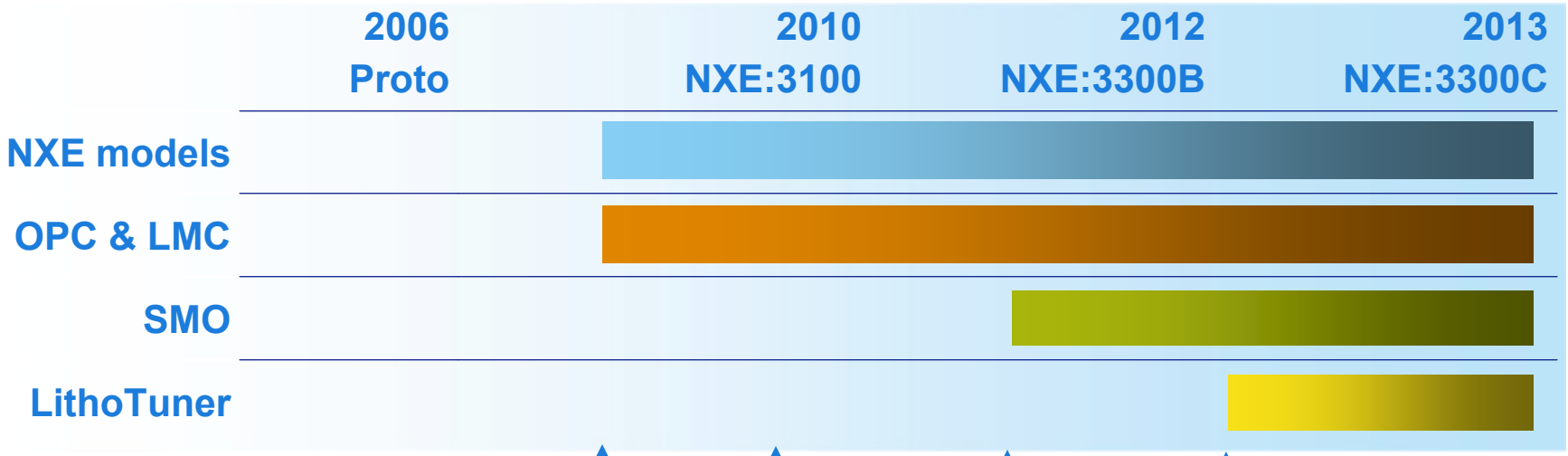
half pitch	32 nm	28	24	22 nm	20	18	16 nm	13	11 nm
k1	0.76	0.66	0.57	0.52	0.47	0.43	0.38	0.31	0.26



ASML

ASML c-lithography roadmap supports EUVL

Support of ASML EUV scanners through Brion products



2009.09 release
1. Beta release
2. Modeling, correction and verification for flare, mask shadowing and low k_1 proximity effect

2010.06 release
1. Production release
2. Models: NXE:3100
3. Optimized Process Correction (OPC)
4. OPC Verification (LMC)

2011.06 release
1. Models: NXE:3100, NXE:3300B
2. Source Mask Optimization (SMO)

2012.06 release
1. Models: NXE:3100, NXE:3300B, 3300C
2. LithoTuner

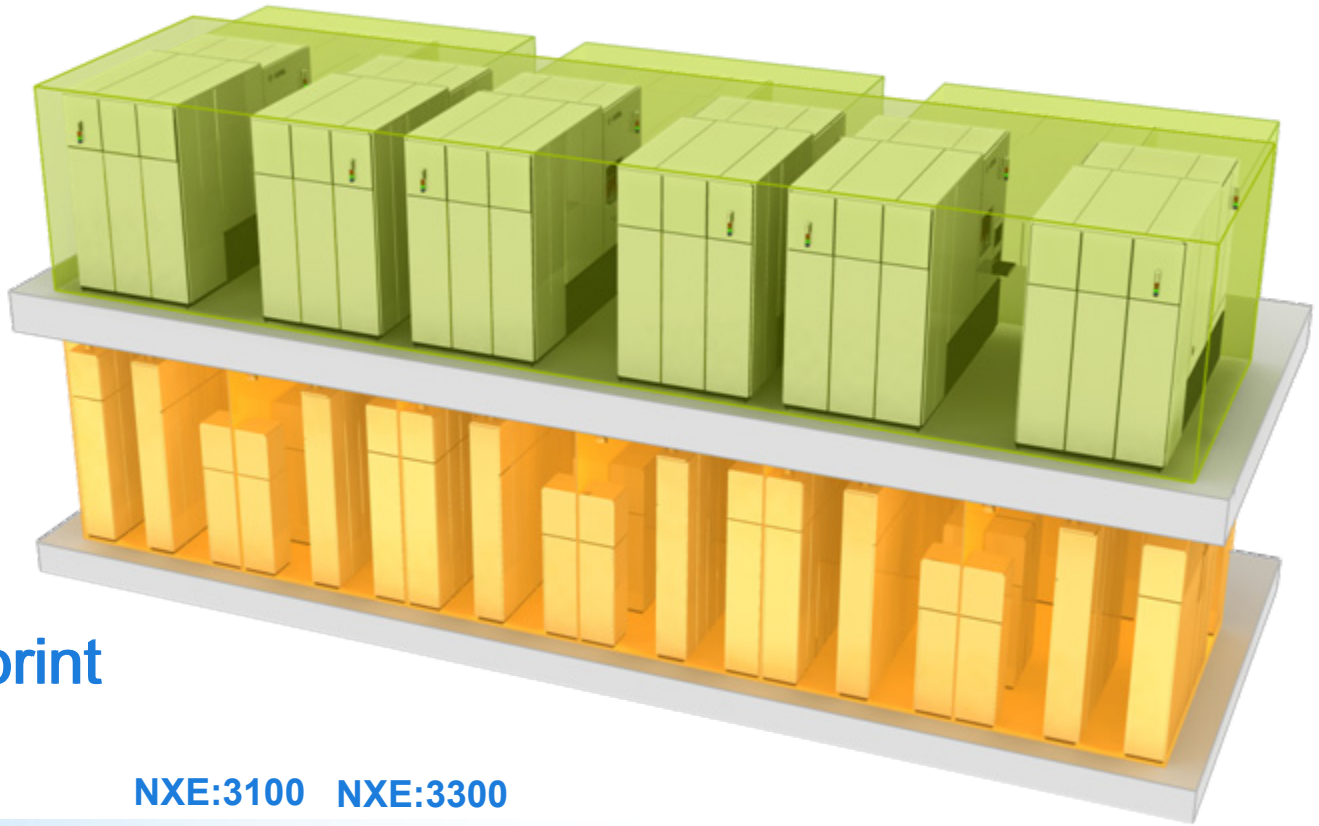
LMC = Lithography Manufacturability Check
SMO = source-mask optimization

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NXE:3300 footprint target is <50% of NXE:3100

Incl. shared service area, for multiple systems in fab.

Service Area
Sub fab Area



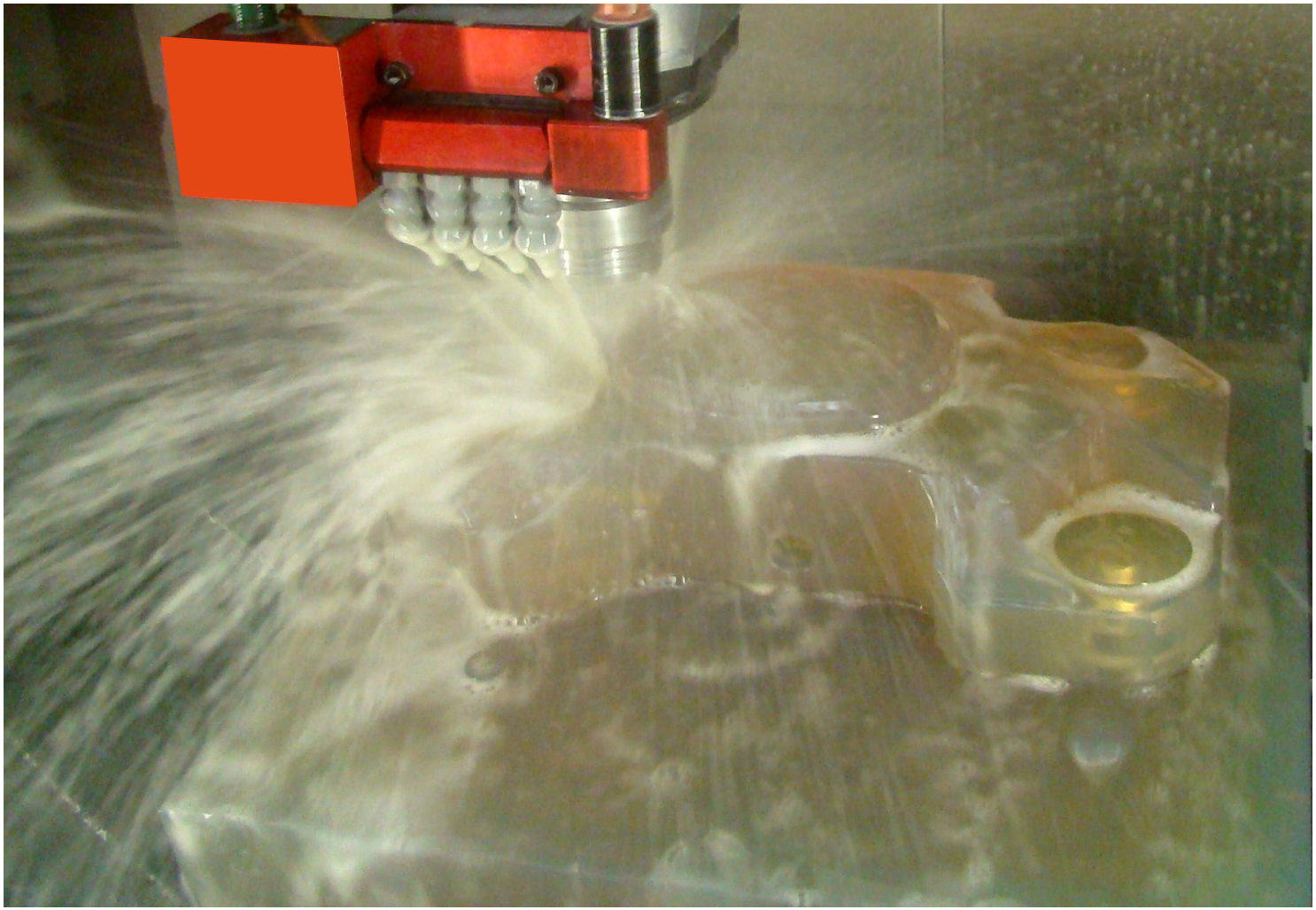
NXE:3300 Footprint

	NXE:3100	NXE:3300
Exposure Unit footprint:	**1**	**0.8**
Subfab footprint (excl. prepumps, abatement)	**1**	**0.4**
Total footprint (incl. service area)	**1**	**0.4**

(all area's normalized to 3100)

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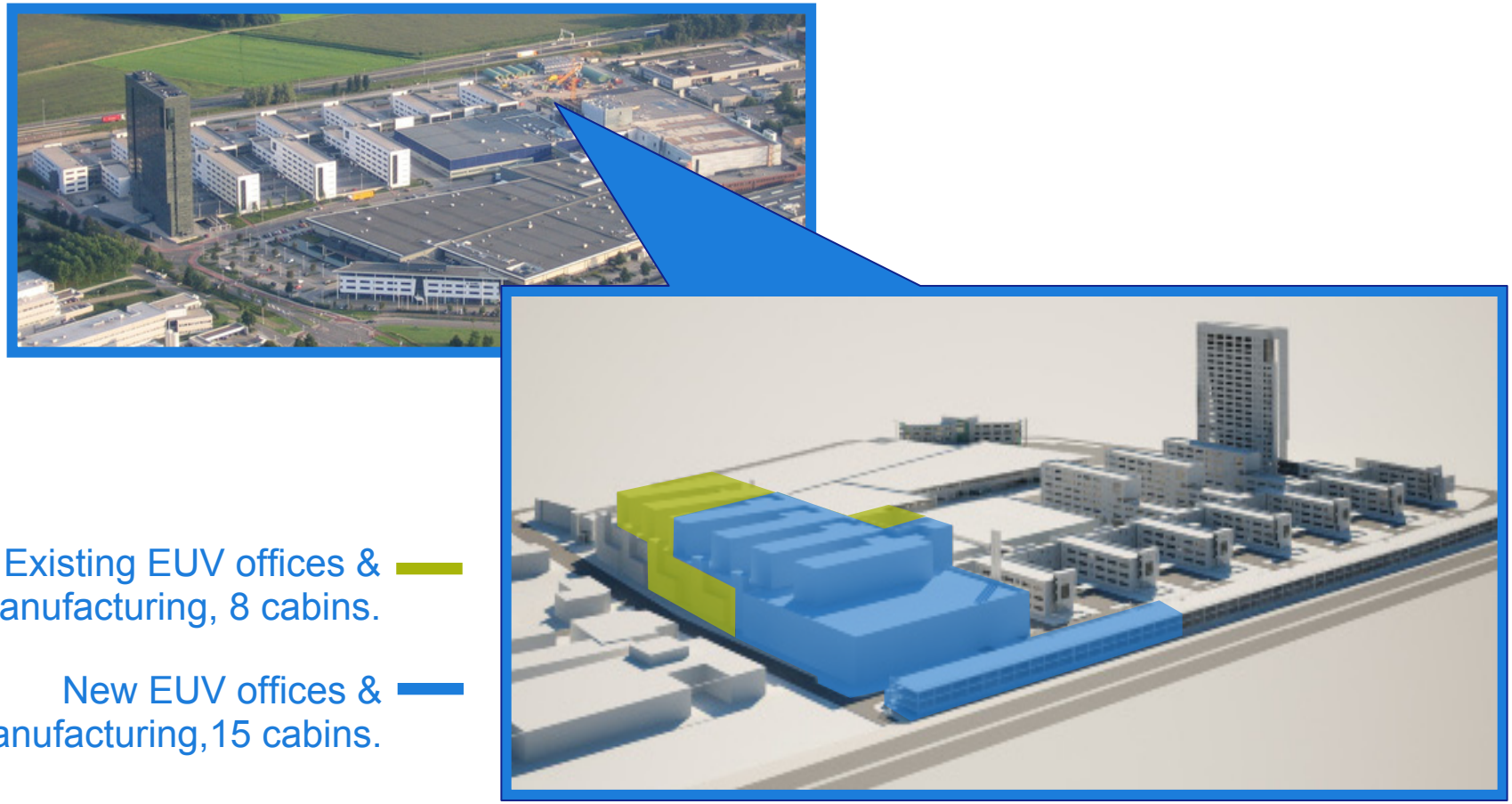
NXE:3300 mirrors are in production at Zeiss



ASML

Construction of new EUV facilities has started

Planned NXE production capacity increases ~3x



Existing EUV offices & manufacturing, 8 cabins.

New EUV offices & manufacturing,15 cabins.

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EUV into production with ASML's NXE platform

- NXE platform established with roadmap for the next 5 years
- 6 NXE:3100 systems ordered by customers, in all market segments, worldwide
- First generation system is in final integration phase for shipment in H2 this year
- Second generation system with high NA optics planned for H1 2012
- NXE platform supported by c-lithography product offerings from Brion
- EUVL is extendible for multiple nodes through NA and wavelength changes.

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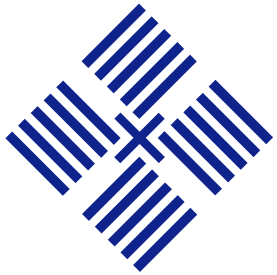
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